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Research Article

Roles of mastery goal and performance goal in undergraduates mathematical modeling competency

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ABSTRACT

Mathematical modeling is an essential tool for resolving intricate practical issues and is crucial for fostering innovation and advancement in the fields of science, engineering, and technology. This study employs a causal correlational research design to examine the effects of mastery goal and performance goal on mathematical modeling competency. Cluster sampling method was used to select 432 undergraduate students enrolled in a mathematics education program in Hebei Province, China. Among these students, 344 (79.6%) are female and 88 (20.4%) are male. Amos 28.0 was used to analysis data with structural equation model. The results shows that both mastery goal and performance goal have significant effects on mathematical modeling competency. The path coefficient from performance goal to mathematical modeling competency is 0.17, which is lower than the path coefficient of 0.23 from mastery goal to mathematical modeling competency. This suggests that through the significant impact of performance goal on mathematical modeling competency, teachers can provide appropriate competitive activities to increase the motivation of achievement focused students. Through the beneficial impact of mastery goal on mathematical modeling competency, teachers can motivate students to prioritize developing understanding and expertise in their learning rather than focusing solely on grades or competitiveness. Really teach students in accordance with their aptitude in teaching.

Keywords: mathematical modeling competency, mastery goal, performance goal, influence

INTRODUCTION

The rapid advancement of science and technology in contemporary society is significantly transforming the functioning of all sectors, creating new demands for professional skills. Modern civilization requires individuals who possess not only expertise in their field, but also creative thinking and the ability to solve complex problems (Glăveanu, 2018). In this context, mathematical modeling competency (MMC) has emerged as a crucial skill, enabling professionals to translate real-world problems into mathematical frameworks, analyzing them using mathematical techniques, and developing effective solutions (Rane, 2023). From environmental science, where computational models predict climate change and guide conservation strategies (Gomes, 2009), to engineering and economics, mathematical modeling plays a pivotal role across disciplines.

Despite its importance, research indicates that the MMC of undergraduates remains underdeveloped. For instance, in Hebei Province, students often demonstrate strong theoretical knowledge but lack the practical skills to apply mathematical principles to real-world problems through modeling (Yang et al., 2024). This gap is exacerbated by inconsistent instructional quality across institutions and limited opportunities for students to engage in hands-on, interdisciplinary projects that foster modeling skills. While prior studies have identified these challenges, they have primarily focused on external factors such as curriculum design and teaching methods, neglecting the role of students' internal motivational drivers, particularly their achievement goals. Wakhata et al. (2023) highlighted the disparity between theoretical knowledge and practical application among students, attributing this gap to inconsistencies in curriculum design and a lack of emphasis on real-world problem-solving in mathematics education. Fauth et al. (2019) examined the impact of teaching methods on students' mathematical modeling competencies, finding that traditional lecture-based approaches often fail to provide students with opportunities for hands-on, interdisciplinary projects. Almazroa and Alotaibi (2023) have explored the role of institutional resources and teacher training in shaping students' modeling competencies, emphasizing the need for better-equipped classrooms and more professional development for educators.

While these studies have provided valuable insights into the structural and pedagogical barriers to developing MMC, they have largely overlooked the psychological and motivational dimensions of learning. For instance, rarely of the studies have systematically investigated how students' achievement goals, such as mastery goals (MGs) and performance goals (PGs) might influence their engagement and success in mathematical modeling tasks. This omission is significant because achievement goals are known to play a critical role in shaping students' persistence, effort, and problem-solving strategies in complex academic tasks (Elliot & McGregor, 2001; Pintrich, 2000). By focusing exclusively on external factors, prior research has failed to provide a comprehensive understanding of the drivers behind students' MMC, leaving a critical gap in the literature.

Achievement goals, which encompass MGs, focusing on learning and understanding and PGs, focusing on demonstrating competence, are critical in shaping students' engagement and persistence in complex tasks like mathematical modeling.

Some research has explored the relationship between achievement goals and various academic outcomes. For instance, studies have demonstrated a significant link between achievement goals and students' problem-solving abilities, with MGs and PGs often positively influencing students' approaches to complex tasks (Elliot & McGregor, 2001; Pintrich, 2000). Similarly, achievement goals have been shown to predict academic performance, with MGs consistently associated with deeper engagement and persistence, while PGs may drive students to achieve higher grades (Miller et al., 2021). Klug et al. (2016) conducted a study using structural equation modeling (SEM) to examine the relationship between MGs and academic achievement among high school students in Austria. Their findings indicated that MGs significantly predicted higher grades, as students who focused on learning and understanding were more likely to engage in self-regulated learning strategies and demonstrate persistence. Diseth and Samdal (2014) used multiple regression analysis to investigate the impact of performance-approach goals on academic achievement among Norwegian university students. Their results showed that students who were motivated by performance-approach goals achieved higher grades, particularly in competitive academic environments. Furthermore, research has highlighted the positive role of both mastery and PGs in enhancing students' achievement and problem-solving skills, though findings on PGs have occasionally yielded mixed results, with some studies suggesting that their impact may vary depending on contextual factors (Senko et al., 2011). Bardach et al. (2019) employed path analysis to explore the relationship between performance-avoidance goals and problem-solving skills in a sample of German secondary school students. Their findings revealed that performance-avoidance goals, fear of failure or negative judgments, were negatively associated with problem-solving abilities. This inconsistency highlights a critical gap in our understanding of how different achievement goals influence MMC, particularly in the context of Chinese higher education, where the development of MMC is both understudied and urgently needed.

Moreover, while some studies have investigated achievement goals using traditional statistical methods, few have employed advanced analytical techniques such as SEM, particularly using tools like Amos, to investigate the complex relationships between these constructs. This study addresses these gaps by utilizing Amos-based SEM to examine how achievement goals directly influence MMC, providing a more nuanced understanding of the underlying mechanisms and contributing to both theoretical and methodological advancements in the field.

This study seeks to address these gaps by investigating the relationship between achievement goals and MMC among Chinese undergraduates. Specifically, it examines how MGs and PGs, both approach and avoidance orientations, impact students' ability to apply mathematical knowledge to real-world problems. By focusing on the motivational underpinnings of MMC, this research provides a novel perspective on how students' goal orientations can be leveraged to enhance their modeling skills. As undergraduates are expected to drive societal progress, addressing this deficiency in MMC is critical to preparing them for future employment demands (Suh et al., 2021).

To address this gap, this study investigates the distinct roles of performance and MGs in shaping undergraduates' MMC. Specifically, it seeks to answer the following research questions:

RQ1: Does PG have a significant effect on MMC among undergraduates?

RQ2: Does MG have a significant effect on MMC among undergraduates?

LITERATURE REVIEW

Mathematical Modeling Competency

MMC is the capacity to transform real-life situations into mathematical models and apply mathematical theories and techniques to analyze and resolve these problems (Rane, 2023). The process of mathematical modeling encompasses more than just basic mathematical computations, it also represents a demonstration of comprehensive capability. The identification of suitable mathematical approaches is necessary to address the complexities and dynamic nature of the real sector. Competency in mathematical modeling is crucial in contemporary society, particularly in the STEM domain. MMC empowers students to convert intricate real-world situations into mathematical problems that are amenable to analysis and resolution (Darjo Felda et al., 2024). The fast advancement of social science and technology has led to a growing need in society for individuals with combination skills in mathematical modeling. The development of MMC is influenced by several interrelated considerations that together shape students' success in mathematical modeling (Stevens, 2004). Instilling inventive thinking in students enables them to confidently attempt and investigate many possibilities during the modeling process. The investment and performance of students in mathematical modeling are mostly determined by their achievement goals and learning motivation. MG and PG jointly influence students' learning strategies and ultimate academic performance. Effective pedagogical approaches and conducive learning settings are crucial for the development of mathematical modeling competencies. When confronted with modeling challenges, students often choose their tactics and allocate their efforts based on the learning objectives they establish.

Relationship Between Mastery Goal and Mathematical Modeling Competency

MGs have been consistently linked to positive learning outcomes, particularly in tasks that demand deep cognitive engagement, such as problem-solving and mathematical modeling. These goals foster intrinsic motivation, encouraging students to adopt advanced learning strategies like critical thinking, self-regulation, and metacognitive control (Akcaoğlu et al., 2022; Tee et al., 2020). Chen and Chang (2024) found that students who pursued MGs were more likely to employ effective problem-solving strategies and persist through challenging tasks, which are critical for developing MMC. Similarly, Kaplan and Maehr (2007) demonstrated that MGs enhance performance in complex tasks by promoting a deep understanding of concepts rather than rote memorization, leading to better academic achievement.

In the context of problem-solving, MGs have been shown to improve students' ability to tackle open-ended and ill-structured problems. For instance, a study by Linnenbrink (2005) revealed that students with MGs were more adept at breaking down complex problems, exploring multiple solutions, and reflecting on their problem-solving processes. This aligns with the demands of mathematical modeling, where students must integrate knowledge, adapt strategies, and evaluate outcomes. Additionally, MGs have been associated with higher levels of academic engagement, as students are more likely to invest effort and seek feedback when they focus on understanding and mastery rather than grades or performance comparisons (Senko, 2019).

While MGs have been widely recognized for their positive impact on deep learning, problem-solving, and academic achievement, their specific influence on MMC remains underexplored in the literature. Meanwhile, the mechanisms through which MGs contribute to the development of MMC, as well as the extent of their impact, are not well understood.

Given this lack of empirical evidence, this research aims to critically analyze the influence of MGs on MMC and explore the underlying pathways through which this influence operates. By examining how MGs shape students' cognitive and metacognitive processes during mathematical modeling tasks, as well as how these effects vary across different instructional contexts, this study seeks to provide a more nuanced understanding of the relationship between MGs and MMC.

Relationship Between Performance Goal and Mathematical Modeling Competency

The theoretical background of PGs is multifaceted, with research indicating both positive and negative effects on students' MMC. Riyanto (2024) suggests that PGs can foster competitiveness, driving students to excel in mathematical modeling tasks. This external motivation may enhance academic achievements, such as the development of modeling skills (Elliot & McGregor, 2001). However, PGs can also induce anxiety and stress, prompting students to rely on superficial learning strategies like rote memorization and test-taking techniques, rather than fostering deep understanding and practical application. Such approaches are often ineffective in mathematical modeling, which requires creative and analytical thinking rather than mere information recall (Ferri, 2018).

The conflicting findings in prior research highlight the dual nature of PGs. On one hand, studies such as Krou et al. (2020) argue that PGs can serve as a motivational force, particularly in competitive academic environments. Students driven by PGs may strive to demonstrate their abilities through modeling tasks, seeking recognition and rewards. This suggests that PGs can enhance competency in certain contexts, particularly where competition is a key driver of achievement. On the other hand, Elliot and Murayama (2008) caution that PGs can lead to fear of failure and avoidance of challenges. This fear may stifle creativity and exploratory thinking, ultimately impairing modeling performance. The negative impact of PGs is particularly evident in collaborative and open-ended tasks, where innovation and risk-taking are essential (Bouffard et al., 2005). This divergence in findings underscores the context-dependent nature of PGs. The motivational benefits may be realized in highly competitive settings, while the pressure associated with PGs may hinder performance in contexts requiring creativity and collaboration.

The inconsistency in findings across studies may stem from differences in research design, cultural contexts, and the specific nature of the tasks being studied. For instance, the competitive academic environment in some cultures may amplify the motivational effects of PGs, while in others, the pressure to perform may exacerbate anxiety and hinder performance. Additionally, the type of modeling task, whether it emphasizes creativity, collaboration, or individual achievement, may influence how PGs affect the outcomes.

Given these complexities, it is crucial to critically examine the role of PGs in mathematical modeling within the context of Chinese education. The unique cultural and educational landscape in China, characterized by high academic expectations and a strong emphasis on competition, may shape the impact of PGs in ways that differ from Western contexts. Further research is needed to disentangle these influences and provide a more nuanced understanding of how PGs affect MMC in diverse educational settings.

Research Gaps

The current research provides sufficient proof that the MG can effectively enhance students' mathematics competency. Nevertheless, the research findings on PG exhibit inconsistencies: certain studies indicate that PGs can enhance mathematical performance, while others suggest that PGs may have an adverse effect on computational performance. The presence of this theoretical discrepancy suggests that there are still unresolved problems and research gaps in the investigation of the influence of achievement goals on MMC. Based on this, this study investigates the precise mechanism by which MG and PG affect MMC to address this research gap. This study seeks to elucidate the function of several success objectives in the enhancement of MMC by means of SEM analysis and investigates if there exist differences in the influence of these goals on MMC.

METHODOLOGY

Research Design

The purpose of this research is to examine the roles of MG and PG in influencing MMC among undergraduates in Hebei Province. Based on the research purpose and to answer the research questions, this research used a non-experimental quantitative research approach with a causal correlation research design.

Participants

Undergraduates majoring in mathematics from Hebei province China made up the population. These individuals were chosen based on their coursework in mathematics and their modeling experiences, which are typical of mathematics education programs. They enrolled in some mathematics lessons such as calculus, statistics and linear algebra. So, they would be familiar with mathematical modeling. Cluster random sampling was appropriate because groups rather than individuals were used for the present research. 432 undergraduates majoring in mathematics participated in the current study. A total of 344 female and 88 male volunteers, the proportion of female is 79.6%, and the proportion of male is 20.4%. The targeted undergraduates' academic year ran from the first to the fourth of the 2023-2024 school year. The current study included the first, second, third and fourth years of data. There were 180 (41.7%) freshmen, 78 (18.1%) sophomores, 103 (23.8%) juniors and 71 (16.4%) seniors. The low proportion of sophomores and seniors may be because some sophomores are doing internships, while seniors are busy with graduation exams and job hunting. A letter outlining the purposes of the study, the tasks involved, the advantages and risks of engaging in the research, and the privacy aspects of the answers that were submitted to them prompted participants to join in the study. During teaching hours, all the chosen undergraduates responded to the voluntary survey. Additionally, they answered 12 questions from the 3 × 2 achievement goal questionnaire and 22 questions from the mathematical modeling task. To complete the questionnaires, each student needs about 30 minutes.

Instruments

The study employs established scales, including the MMC test questionnaire and the MG and PG scale, which were initially translated from their original English versions into Chinese. During the translation process, particular attention was paid to maintaining the accuracy of the original content and the integrity of the intended meaning to avoid any loss of information due to language conversion. However, recognizing the importance of cultural relevance, the translated questions were further adapted to align with the linguistic, cultural, and educational context of undergraduate students in China. For instance, the background or situational content in some questions was localized to reflect the students' learning and living environments more closely. This adaptation process ensured that the questions were not only linguistically accessible but also culturally resonant, thereby enhancing their applicability to the target population.

Despite these efforts, the study acknowledges that the use of established scales in a new cultural context requires rigorous validation to ensure their reliability and validity. To address this, a pilot study with 119 undergraduates was conducted with a sample of undergraduate students in Hebei Province to test the adapted scales. The pilot's study aimed to identify any potential issues related to comprehension, cultural relevance, or response patterns. Based on the feedback, minor adjustments were made to the wording and structure of certain items to improve clarity and cultural appropriateness. Additionally, statistical analyses, such as Cronbach's alpha for internal consistency and confirmatory factor analysis for construct validity, were performed to assess the reliability and validity of the adapted scales in the Chinese context. These validation tests confirmed that the scales retained their psychometric properties while being suitable for use in this specific cultural and educational setting.

By combining careful translation, cultural adaptation, and empirical validation, the study ensures that the scales are not only theoretically sound but also practically relevant for assessing MMC and goal orientations among undergraduate students in Hebei Province.

Mathematical modeling competency test questionnaire

Haines and Crouch (2001) and Niss (2010) developed a 22-item scale that is the main instrument employed in the literature to determine the MMC of undergraduate students. There are 22 test questions in this

Table 1. Reliability and validity analysis criteria (Source: Sharma, 2016; Traymbak et al., 2024)

KMO value	Evaluation	Cronbach's alpha	Evaluation
> 0.8	Great	> 0.9	Good
0.8 ≥ KMO ≥ 0.7	Good	0.9 ≥ α ≥ 0.7	Acceptable
0.7 > KMO ≥ 0.6	Acceptable	< 0.7	Poor
< 0.6	Poor		

questionnaire, and each question is designed for evaluating a distinct sub-dimension of MMC. This scale has a good reputation and meets all validity and reliability requirements. It is a helpful instrument for evaluating the mathematical competencies of undergraduates. Using the eight-dimensional scale created by Haines and Crouch (2010), this study provides a comprehensive and in-depth investigation regarding MMC among undergraduate mathematics majors.

Mastery goal and performance goal scale

The achievement goal questionnaire is based on the 3 × 2 achievement goal model developed by Elliot et al. (2011). This questionnaire consists of six categories, which are divided into MG (task-approach, task-avoidance, self-approach, and self-avoidance goal) and PG (other-approach and other-avoidance goal). There are three items in each dimension. There are eighteen questions on the questionnaire, each representing one of the six dimensions on a seven-point Likert scale. A 7-point scale is used in the 3x2 achievement goal questionnaire (1 being strongly disagreed and 7 being highly agreed).

Data Analysis

Reliability and validity analysis serves as the foundation of SEM analysis, ensuring that the measurement model is both reliable and valid. Reliability is assessed through Cronbach's alpha and composite reliability (CR). A Cronbach's alpha is greater than 0.7 and a CR value exceeding 0.7 indicates that the measurement tool exhibits strong internal consistency and CR. Validity is evaluated using Kaiser-Meyer-Olkin (KMO) and average variance extracted (AVE). A KMO value above 0.7 and an AVE value greater than 0.5 demonstrate that the measurement tool has excellent convergent validity. Additionally, the skewness and kurtosis values of each item must fall within the range of –1.96 to 1.96 at a significance level of 0.05 to meet the basic normality requirements for a latent variable measurement model. These criteria, summarized in **Table 1**, are used to interpret the coefficients, which range from 0 to 1.

Amos 28.0 is used to conduct confirmatory factor analysis to determine whether the dimensionality and factor-loading pattern discovered are suitable for the Chinese context and test the hypothesized model. According to Baharum et al. (2023), the following standards were applied: Tucker-Lewis index (TLI) > 0.90, comparative fit index (CFI) > 0.90, incremental fit index (IFI) > 0.90, root mean square error of approximation (RMSEA) < 0.08, goodness-of-fit index (GFI) > 0.90, adjusted goodness-of-fit index (AGFI) > 0.90, normed fit index (NFI) > 0.85, standardized root mean square residual (SRMR) ≤ 0.08.

In structural models, the strength and direction of relationships between variables are typically assessed using standardized path coefficients (Grapentine, 2000). A path coefficient less than 0.1 indicates a weak relationship, while a value between 0.1 and 0.3 suggests a moderate relationship. A path coefficient greater than 0.3 signifies a strong relationship. Additionally, a p-value of less than 0.05 is required to confirm the statistical significance of the path coefficient.

RESULTS

Analysis of Validity and Reliability

For MMC, MG and PGs, the Cronbach's alpha coefficients are 0.856, 0.906, and 0.928, correspondingly. The KMO values are 0.857, 0.892, and 0.851, respectively. The AVE values are 0.588, 0.608, 0.501. The CR values are 0.82, 0.85, 0.84. Since each value satisfies the required standards, the reliability and validity coefficients are also considered satisfactory. Each item's skewness and kurtosis values fall between –0.30 and 0.90 at a significance level of 0.05 for each value for a latent variable measurement model to meet the conditions for basic normality.

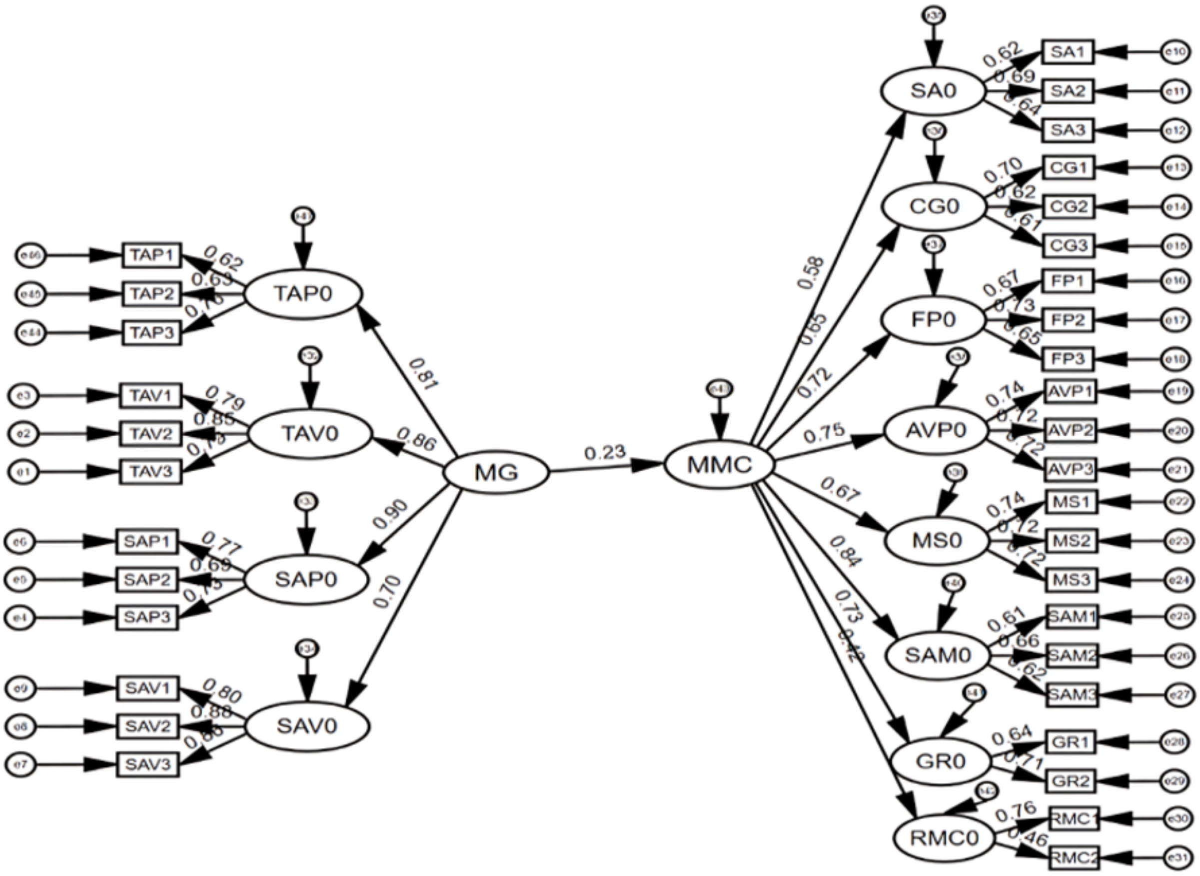

Figure 1. SEM of MG and MMC (Source: Authors' own elaboration)

Table 2. Significance test results of direct paths

Pathway	Estimate	Standard estimate	Standard error	t-value	p-value
MG → MMC	0.066	0.232	0.015	4.517	***
PG → MMC	0.045	0.171	0.014	3.266	0.001

Table 3. Fit indices of SEM

Pathway	χ^2/df	RMSEA	GFI	AGFI	CFI	NFI	TLI	SRMR
MG → MMC	1.807	0.034	0.927	0.916	0.949	0.893	0.945	0.0424
PG → MMC	1.608	0.03	0.947	0.937	0.969	0.922	0.965	0.0366

Analysis of Confirmatory Factors

Using Amos 28.0, a structural equation modeling was constructed, with MG as the independent variable and MMC as the dependent variable. The model was used to verify the impact of MG on undergraduates' MMC. The results are shown in **Figure 1**, **Table 2** and **Table 3**.

The results of the main effects structural model test, as shown in **Table 2**, indicate that the path coefficient of MG to MMC is 0.23, suggesting a moderate positive impact. The C.R. value is 4.517, exceeding the threshold of 1.96, and the p-value is below 0.001, confirming statistical significance. This demonstrates that MG has a significant influence on MMC, thereby addressing **RQ1**. In summary, MGs significantly enhance undergraduates' MMC.

Table 3 presents the evaluation of the relationship between MG and MMC using different fit indices in the SEM analysis. Based on the fit indices, the results demonstrate that the model offers a satisfactory match to the data. The χ^2/df is 1.807, suggesting a satisfactory fit (≤ 5). The RMSEA is 0.034, indicating a satisfactory fit (≤ 0.08). The GFI is 0.927, AGFI is 0.916, CFI is 0.949, NFI is 0.893, TLI is 0.945, and SRMR is 0.0424. All indicators passed the standard, and the model was successfully verified.

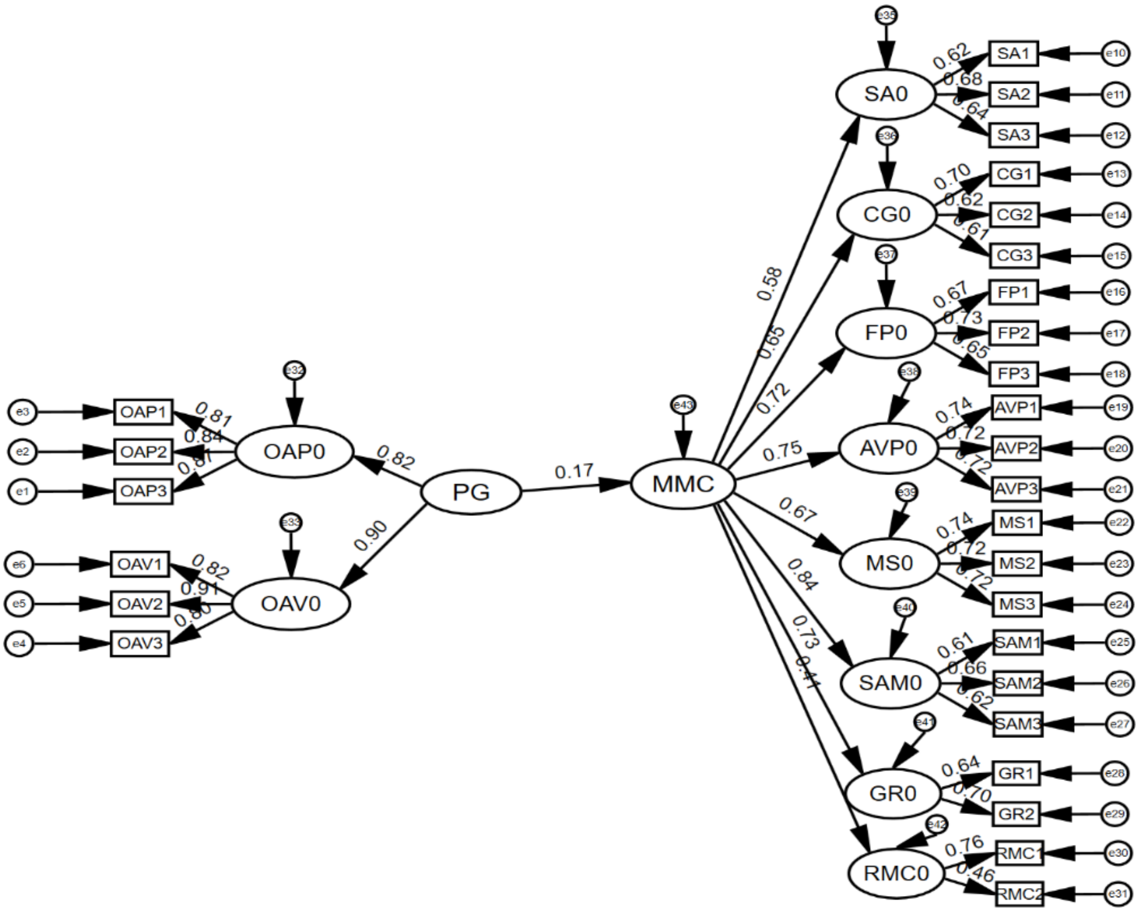

Figure 2. SEM of PG and MMC (Source: Authors' own elaboration)

Using Amos 28.0, a structural equation model was constructed, with PG as the independent variable and MMC as the dependent variable. The model was used to verify the impact of PG on undergraduates' MMC. The results are shown in **Figure 2**, **Table 2** and **Table 3**.

The results of the main effects structural model test in **Table 2** show that the path coefficient of PG to MMC is 0.17, indicating a moderate positive impact. The CR value is 3.266, exceeding the threshold of 1.96, and the p-value is below 0.001, confirming statistical significance. This demonstrates that PG significantly influences MMC, addressing **RQ2**. In summary, PGs positively contribute to undergraduates' MMC.

Table 3 presents the evaluation of the relationship between PG and MMC using different fit indices in the SEM analysis. Based on the fit indices, the results demonstrate that the model offers a satisfactory match to the data. The χ^2/df is 1.608, suggesting a satisfactory fit (≤ 5). The RMSEA is 0.03, indicating a satisfactory fit (≤ 0.08). The GFI is 0.947, AGFI is 0.937, CFI is 0.969, NFI is 0.922, TLI is 0.965, and SRMR is 0.0366. All indicators passed the standard, and the model was successfully verified.

DISCUSSION

The field of mathematical modeling offers a methodical and functional approach to address intricate real-world situations by transforming practical issues into mathematical problems (Osaba et al., 2021). Within the STEM domain, mathematical modeling serves as the fundamental instrument for implementing theoretical knowledge into real-world scenarios, fostering critical thinking and problem-solving skills among college students. This study investigates the impact of MG and PG on the mathematical modeling competencies of undergraduates, contributing to the broader discourse on achievement goal theory and its implications for educational practices.

The findings of this study confirm that MG significantly enhances students' MMC, aligning with prior research on mathematics achievement and problem-solving abilities. MG-oriented students are more likely to persist through challenges, seek feedback, and refine their models, leading to improved competency in mathematical modeling (Hidayat et al., 2018). This is consistent with Nilimaa (2023) assertion that MGs motivate students to develop a deep understanding of knowledge, thereby enhancing their ability to tackle complex tasks such as mathematical modeling. Recent studies have further emphasized the role of MGs in promoting adaptive learning strategies, such as self-regulation and metacognitive skills, which are crucial for effective mathematical modeling (Ishak et al., 2025).

The four components of MGs provide a nuanced understanding of how these goals influence modeling strategies. Task-approach goals drive students to achieve a comprehensive understanding and exceptional performance in mathematical modeling problems, fostering creativity and innovation (Huang et al., 2021). Conversely, task-avoidance goals may lead students to adopt a cautious approach, prioritizing error avoidance over exploration. Self-approach goals motivate students to continuously improve their competencies, while self-avoidance goals may induce anxiety, hindering their willingness to take risks in modeling tasks. These findings underscore the importance of fostering MGs in educational settings to enhance students' modeling competencies.

The study also reveals a positive, albeit smaller, effect of PGs on MMC. This finding aligns with Locke and Latham's (2015) goal-setting theory, which posits that PGs can enhance motivation and effort, particularly in competitive contexts. Students with PGs are often driven by the desire to outperform their peers, leading to increased effort and strategic learning techniques, such as focusing on key concepts and seeking feedback to improve their models.

However, the literature presents mixed findings on the impact of PGs. While some studies suggest that PGs can enhance mathematical performance (Sides & Cuevas, 2020), others argue that they may lead to short-term success at the expense of long-term understanding (Benden & Lauermann, 2021). For instance, students with PGs may avoid complex problems that require deeper thinking, opting instead for simpler tasks that ensure success. This avoidance can stifle creativity and innovation, which are essential for high-level MMC. Despite these concerns, the current study demonstrates a significant positive effect of PGs on MMC, albeit with a smaller path coefficient 0.17 compared to MGs 0.23. This finding enriches achievement goal theory by highlighting the nuanced role of PGs in educational contexts.

CONCLUSION

The results of this study provide further evidence that MG have a positive impact on MMC. SEM analysis found that task-goals and self-goals have a significant positive impact on MMC, while PG also has a significant positive impact on MMC. By summarizing these results, we believe that achievement goal is a critical and important factor. Both achievement goal and their sub-dimensions can be affected by MG, thereby affecting MMC. Research reveals the differential impact of MG and PG on students' MMC. This provides teachers with a basis for developing personalized teaching strategies based on students' target tendencies. For students whose main goal is mastery, teachers can design challenging questions to encourage in-depth discussion and reflection. For students whose goal is performance, teachers can provide appropriate competitive activities to stimulate their learning motivation. By emphasizing the positive role of MG in mathematical modeling competencies, educators can encourage students to pursue the development of understanding and skills in their learning rather than focusing solely on grades or competition. Such teaching strategies help students adopt a deeper way of thinking when facing complex problems, thereby improving their ability to solve practical problems. Teachers can also use these findings to design more effective assessment methods that focus on students' progress and understanding rather than just their final grade.

Implications

Theoretical aspect

The study confirmed the distinct impacts of MG and PG on MMC using SEM, therefore offering empirical validation for the theory of achievement goals. The study's identification of the processes via which MG and

PG impact mathematical modeling competencies enhances our comprehension of the interaction between these two goals and learning behavior and academic achievement. The present theoretical contribution offers a novel viewpoint for continuing study and motivates scholars to delve deeper into the significance of achievement goal within various academic and cultural settings.

Practical aspect

The attainment of MG greatly enhances students' mathematical modeling competencies, particularly when engaging with intricate issues and overcoming obstacles. This discovery offers educators valuable direction, indicating that educators should prioritize MG in the teaching process to motivate students to strive for increased knowledge comprehension and skill enhancement, rather than only concentrating on performance. Employing this approach can facilitate the cultivation of more robust problem-solving and creative abilities among students when confronted with intricate assignments like mathematical modeling. Effective development of students' mathematical modeling skills is crucial in STEM education. This study demonstrates the influence of achieving a goal on this skill, offering empirical validation for the development and instructional approaches of STEM courses. Educational policymakers and curriculum designers can utilize these findings to create curricula and activities that target the enhancement of student MG therefore ensuring the development of students' overall competencies in science, technology, engineering, and mathematics.

Limitations

This sample was restricted to undergraduate students in Hebei Province, therefore potentially constraining the generalizability of the research findings. Educational attainment objectives, metacognitive skills, and mathematical modeling proficiency may vary across students from diverse geographical areas and cultural origins. Hence, the generalizability of the research findings to different geographical areas or cultural contexts should be approached with prudence. Further investigation can broaden the sample range to encompass students from diverse geographical areas, cultural backgrounds, and educational systems to validate the applicability of these findings. Despite the use of control measures in this study, there remain unaccounted confounding variables that could impact MMC. These variables include students' prior mathematical knowledge, particular forms of learning motivation, and the accessibility of educational resources. The research findings may be influenced by these uncontrollable variables. Subsequent investigations should endeavor to include more control variables to enhance the precision and explanatory capacity of the findings. However, this study nonetheless offers significant insights into comprehending the correlation between achievement goals and competency in mathematical modeling. These constraints not only indicate the extent and methodological decisions made in the present study but also offer important points of reference for future research.

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AI declaration: No artificial intelligence tools were used in the generation, analysis, writing, or revision of this study. All work was done by the authors.

Declaration of interest: The authors declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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